Back to the Future: A Comparison of Ecosystem Structure of the Strait of Georgia 100 Years ago And Present Day

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Introduction

Over the last 100 years humans have increasingly impacted marine ecosystems due to harvesting, pollution, and destruction of habitat. As a consequence, marine ecosystems observed today are different from a century ago. In this paper we construct past and present-day models of the Strait of Georgia ecosystem using Ecopath 3.0 modeling software (Christensen and Pauly, 1996a; Christensen and Pauly, 1996b). Recent fisheries literature and statistics were used as inputs for the present-day model, while a 100-year model was constructed using anecdotal, historical, and scientific sources from that period. To further validate the information, a workshop was held in November 1997, and suggested improvements were subsequently incorporated into the models. The main differences between the two models are explained by changes in relative abundance of organisms, which includes species now extirpated from the Strait. A comprehensive discussion of model inputs, methods, workshop discussions, and sources of information can be found in (Pauly et al., in press). In this paper, we summarize the methods used, the major differences between the two models, and a discussion of the implications.

Methods

The study area of the Strait of Georgia used in this project is defined by the body of water separating the British Columbia mainland and the Southern half of Vancouver Island between Campbell River (50° 05' N) and the southern Gulf Islands (48° 50'N). The area of this region is 6900 km^2, which is the value used as area input for the models.

An existing mass-balance model of the Strait of Georgia (Venier, 1996) served as a skeleton for building the present-day model. Ten functional groups were added and the model changed from a summer to a yearly average model. For many groups, the Ecopath input parameters including diet composition, production/biomass (P/B), consumption/biomass (Q/B), and/or ecotrophic efficiency (EE) remained unchanged, while the effort was concentrated on obtaining up-to-date biomass and harvest estimates from published scientific sources. Based on the present-day model, a model representing the Strait of Georgia 100 years ago (1890s) was constructed. Information for this model came from a variety of sources including traditional ecological knowledge, expert opinion, and historical sources (Wallace, in press). Two functional groups (sturgeon and baleen whales) were added, while other groups were modified when it could be documented that their abundance 100 years ago was different than today (Table 1). No changes of the P/B and Q/B values were made between the present-day and the 100-year model. For a full description of model inputs and flow diagrams see Dalsgaard et al. (in press).

Table 1. Biomass estimates of functional groups used in the two models of the Strait of Georgia. Dashes indicate that no value was entered.

Group / parameter	Present Biomass ($t{\cdot}km^{-2}$)	Past Biomass ($t{\cdot}km^{-2}$)	Ratio Past:present
Phytoplankton	31.1	31.0	Same
Kelp & sea grass	20.3	25.0	1.2
Herbivorous zooplankton	15.5	15.6	Same
Shellfish	220.5	220.5	Same
Grazing invertebrates	400.0	400.0	Same
Carnivorous zooplankton	33.3	32.3	Same
Predatory invertebrates	9.1	11.0	1.2
Shorebirds	0.001	0.002	2
Jellyfish	15.0	15.0	Same
Herring	6.0	7.0	1.2
Eulachon	0.7	1.3	2.0
Small pelagics	14.5	15.0	Same
Seabirds	0.02	0.02	Same
Misc. demersal fishes	12.6	38.0	3
Baleen whales	---	1.9	NA
Hake	35.5	9.0	0.25
Chinook & coho	0.7	6.5	10
Dogfish	8.7	8.7	Same
Sturgeon	---	0.02	NA
Transient salmon	6.4	13.0	2
Toothed whales	0.04	0.20	5
Halibut	0.004	0.14	35
Lampreys	0.2	0.2	Same
Lingcod	0.05	1.5	30
Seals & sea lions	0.6	0.47	0.8
Transient orcas	0.004	0.004	Same
Detritus	0	7.0	NA

Results and Discussion

The results observed fall into four categories of functional groups: 1) those that no longer exist in the Strait; 2) those whose relative abundance has changed; 3) those for which sources indicate no abundance change; and 4) those for which no historical sources are available and therefore are left the same as present.

Groups That No Longer Exist in the Strait

These results are the most interesting, because the ecological impact of completely removing a functional group has enormous ecological impact. There are three groups at present considered to be nonexistent from an ecological point of view: baleen whales (humpbacks), halibut, and sturgeon. Although some whaling took place in the Strait from 1866 to 1873, most of the whaling occurred in 1907–08. In that year alone, 97 humpbacks were harvested, many from the mouth of the Fraser River (Merilees, 1985). After just two years, all baleen whales had been killed. The presence of humpbacks, a large predator of herring in the Strait, would alter the flow of energy. Halibut is another top predator that was fished to ecological extinction early in the century. The biomass 100 years ago is only a crude estimate. Catch records from the Canada Sessional Papers (1897) listed a catch from 1896 of 0.142 $t{\cdot}km^{-2}$ landed at ports in the Strait. With no better data available, this figure was used as a biomass estimate for the Strait for the 100-year model. Sturgeon, although not found throughout the Strait, were in large abundance in the Fraser River Estuary—where, in 1897, 517 tons were landed (Echols, 1995). All three of these species, from an ecological point of view, disappeared close to a century ago and have yet to return.

Groups with Significant Changes in Abundance

There are numerous groups whose abundance has changed dramatically over the last 100 years. The most dramatic changes were found to be in lingcod, miscellaneous demersal fish, resident salmon, toothed whales, and hake. Lingcod supported a commercial fishery in the Strait from the 1870s to 1990. The estimate of lingcod 100 years ago was based on a model by Martell and Wallace (in press) that indicates that the biomass has decreased by 30 times. Lingcod are a top predator in structuring rocky reef fish communities. The loss of this substantial biomass has undoubtedly lead to cascading impacts throughout the system. Evidence from catch-per-unit-effort (CPUE) data on demersal fish (sole and rockfish) from Levy et al. (1996) showed that from the late 1970s to the early 1990s, the CPUE decreased to one-third of its original value. Based on this, the biomass of the group was conservatively assumed to have been three times higher 100 years ago. The resident stocks of chinook and coho salmon have decreased by an order of magnitude (Walters, pers. com.). The cause of salmon decline is likely a result of multiple factors. Toothed whales are composed of resident orcas and porpoises. Porpoises were an important component of Coast Salish diet, and bone remains have been found in many middens in the Strait of Georgia region (Calvert, 1980). Porpoise were also caught and combined with dogfish in the early reduction fisheries (Canada, 1887). No exact biomass data exist, but five times was used as an estimate. Finally, hake constitute the one functional group for which estimates of abundance are greater in the present model. It is thought that hake are occupying an ecological niche once used by lingcod and other demersal fishes.

Groups with No Abundance Changes

From Table 1, it is apparent that many groups have remained the same. This is either because information available suggests that the abundance has not changed, or there is no information available and therefore we assumed the same value. Considering how difficult it is to get present-day estimates of certain groups, it is not surprising that data for 100 years ago do not exist. This is true for many of the lower trophic-level invertebrates. More interesting are groups such as dogfish and herring, for which information sources exist, but yet the abundance is considered to be the same as today. Both of these species are considered to be important components in structuring the ecosystem of the Strait.

Herring was the most controversial input of the mode,l because it is both an ecologically important group and also the center of a continuous political debate. The final biomass used was based on expert opinion that suggested that the overall present-day biomass was equal to historic levels (Wallace, in press). The difference is that the Strait once supported numerous year-round resident stocks that may have composed one-third of the biomass. At present, the migratory stock makes up 95% of the herring biomass and uses a smaller area of the Strait when present. The overall amount of herring available to other species has likely decreased (Dalsgaard et al., in press).

Conclusion

Although many gaps in knowledge exist regarding the structuring of ecosystems, it is agreed upon that the Strait of Georgia has undergone an ecological transformation from the effects of human predation on marine organisms. Presumably, if overharvesting (or any other human activity) is responsible for the declines, then it is possible from an ecological point of view to rebuild the system. Rebuilding of ecosystems from a single species perspective cannot work due to the complexities and uncertainties of marine species and systems. Based on theories of ecosystem development, total biomass accumulates as an ecosystem moves towards maturity (Odum, 1969; Christensen and Pauly, 1998). To rebuild a system requires a decrease in biomass removal of all species. Marine protected areas where human harvest is limited have shown to be effective in building up biomass and restoring ecological processes, and may be the best way to approach the problem.

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References

Calvert, S. G. 1980. A cultural analysis of faunal remains from three archaeological sites in Hesquiat Harbour, British Columbia. Ph.D. diss., Univ. British Columbia, Vancouver, 336p.

Canada, Sessional Papers. 1887.

Canada, Sessional Papers. 1897

Christensen, V., and D. Pauly. 1996a. Ecological modeling for all. Naga, the ICLARM Quarterly 19(2).

Christensen, V., and D. Pauly. 1996b. Ecopath for Windows: a User's Guide. ICLARM, Makati City, Philippines. 71 pp.

Christensen, V., and D. Pauly. 1998. Changes in models of aquatic ecosystems approaching carrying capacity. Ecological Applications 8(1): 104-109.

Dalsgaard, J., S. Wallace, S. Salas, and D. Preikshot. in press. Mass-balance models of the Strait of Georgia today, one hundred, and five hundred years ago. In Pauly et al. in press.

Echols, J. C. 1995. Review of Fraser River white sturgeon (*Acipenser transmontanus*). Department of Fisheries and Oceans, Vancouver, B.C., Canada. 33 pp.

Levy, D. A., L. U. Young, and L. W. Dwernychuk. 1996. Strait of Georgia fisheries sustainability review. Hatfield Consultants Ltd. Vancouver, B.C., Canada. 441 pp.

Martell, S., and S. Wallace. in press. Estimating historical lingcod biomass in the Strait of Georgia. In Pauly et al. in press.

Merilees, B. 1985. The humpback whales of Georgia Strait. Water Journal of the Vancouver Aquarium, Vol. 8. Vancouver, B.C., Canada.

Odum, E. P. 1969. The strategy of ecosystem development. Science 164: 262-270.

Pauly, D., T. Pitcher, N. Haggan, and D. Preikshot. in press. Back to the future: An ecosystem analysis of the Strait of Georgia past and present. Fisheries Centre Research Reports Vol. 7(1).

Venier, J. 1996. Balancing the Strait of Georgia model, p. 74-77. In D. Pauly and V. Christensen, eds. Mass-balance models of North-eastern Pacific ecosystems. Fisheries Centre Research Reports, University of British Columbia, Vancouver, B.C., Canada.

Wallace, S.S. in press. Sources of information used to create past and present ecosystem models of the Strait of Georgia. In Pauly et al. in press.

Walters, C. Pers. Comm. November 21-22, 1998. Back to the Future Workshop. First Nations House of Learning, University of British Columbia, Vancouver, B.C., Canada.